NOAA Joint Hurricane Testbed (JHT) Year 2 Mid-Term Progress Report

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Project title: *Advanced Applications of the Monte Carlo Wind Probability Model*
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1. Long-Term Objectives and Specific Plans to Achieve Them

Under previous JHT support a program for estimating the probability of occurrence of 34, 50, and 64 kt winds was developed by NESDIS and CIRA. A Monte Carlo (MC) method is utilized to combine the uncertainty in the tropical cyclone track, intensity and wind structure forecasts. The MC probability program has been used operationally at NHC, CPHC and JTWC since 2006. The model was upgraded in 2010 to include situation-dependent track forecast uncertainty through the Goerss Predicted Consensus Error (GPCE) product, which was also developed under previous JHT support.

In the current two-year project, four new applications of the MC model are under development. These include (1) Landfall timing and intensity distributions; (2) Methods for using the MC model to enhance WFO local products; (3) Probabilities integrated over coastal segments; (4) Automated guidance for issuing coastal watches and warnings.

The current project also includes four refinements to the MC model code. These include (1) A procedure to adjust the model time step for fast moving and small storms; (2) Modification of the azimuthal interpolation routine that occasionally leads to inconsistent probability values for 34, 50 and 64 kt winds; (3) Evaluation of the spatial interpolation method that sometimes results in inconsistencies between the gridded and text probabilities; (4) Evaluation of the underlying wind radii model utilized by the MC model.

The timeline for this project is provided in the Appendix.

2. Accomplishments

The accomplishments below are described for each of the four new applications and four code refinements. All of the tasks are nearly completed. Additional forecaster evaluation is needed to determine the usefulness of the applications, which will be obtained during the 2011 hurricane season. Recent results were also presented at the Interdepartmental Hurricane Conference in March, 2011 (DeMaria et al, 2011a).

Application 1, landfall timing and intensity distributions.

The MC model code was modified to create a new output file that includes the track, intensity and wind radii of all 1000 realizations. A separate post-processing routine was developed that calculates the landfall timing and intensity distributions for a set of user defined points. Because this application requires a forecaster to select points of interest, a prototype graphical user interface called Hurricane Landfall Probability Applications (HuLPA) was developed for demonstration of these capabilities. HuLPA is java-based, but a similar application could be developed in the ATCF framework. Figure 1 is a screen capture of the HuLPA application run on a Windows system. Because of the use of java, the program also runs on Linux systems. The user selects from a set of storm cases (Hurricane Gustav initialized at 06 UTC on 31 August 2008 in this example), and then the program displays the NHC forecast track and intensity. The user then selects the coastal points of interest (Sabine Pass to Pascagoula in this example), and the application of interest (landfall timing and intensity distribution in this example). The user can modify the selected points or forecast case and re-run the application.

The HuLPA program was installed at NHC for evaluation during the 2010 hurricane season. Based on forecaster feedback during Hurricane Alex, the display was modified to also include the probability of the storm reaching at least tropical storm and each of the five Saffir-Simpson Hurricane categories at any time during the forecast period. The middle panel in Fig. 1 shows that information for the Hurricane Gustav example.

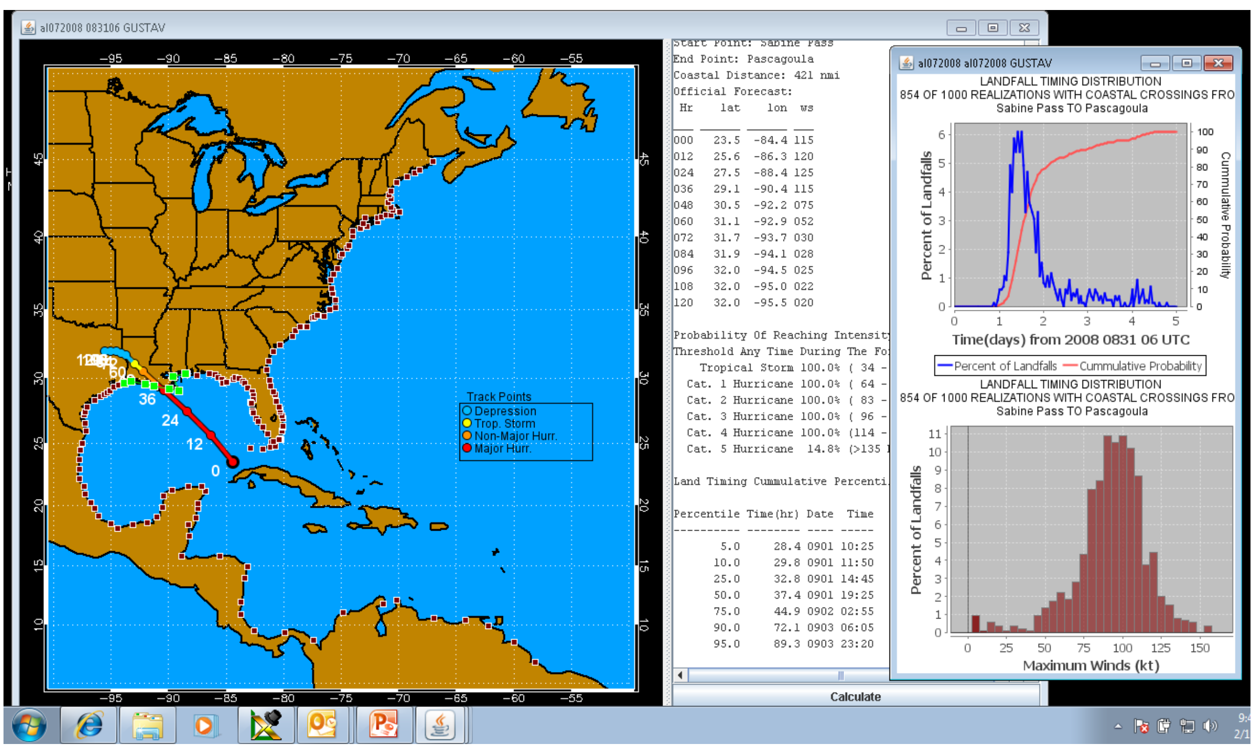

Figure 1. Screen capture of the HuLPA program for a case from Hurricane Gustav (2008) that shows the landfall intensity and timing application.

Application 2. WFO local applications.

The initial work for this application was completed in Year 1 as described in the Year 1 final report. In coordination with Pablo Santos from the Miami, FL WFO and Dave Sharp from the Melbourne, FL WFO, an extensive verification of the 12 h incremental probabilities was performed for coastal and inland points to help them refine their WFO applications. 400 forecast cases from 20 landfalling storms from the 2004-2008 hurricane seasons were run with the most current version of the MC model (the 2009 version). In Year 2, addition verification cases from 2010 were provided to refine the WFO application. The previous coastal verification cases were re-run with the 2010 version of the model and two versions were provided for comparison (with and without the GPCE input). A comparison of the two versions provided confirmation that the GPCE input improves the skill of the MC model. The WFO applications are being developed from the GPCE version.

Application 3. Integrated probabilities

The ability to estimate the probability of 34, 50 and 64 kt winds at any point along a user specified section of coastline was added to the HuLPA program, which was tested during the 2010 season. Forecaster feedback during the landfall of Hurricane Karl in Mexico suggested that the algorithm underestimated the integrated probabilities. Further analysis showed that the coastal points used in the numerical integration were too far apart for a small storm like Karl. The program was modified to reduce the spacing of the coastal points. This version will be tested during the 2011 season.

Application 4. Automated watch/warning guidance

The algorithm for providing automated coastal hurricane and tropical storm watch/warning guidance was not available in HuLPA during the 2010 season, but is now included in the most recent version. The algorithm uses probability thresholds to provide guidance on the end points of the U.S. watches and warning. The method uses the probabilities from the previous 48 h of MC model runs, and requires a lower probability value for lifting a watch or warning than putting one up. The thresholds were determined by comparing the objective watch/warning guidance to those issued by NHC for 2004-2009. Figure 2 shows an example of the watch/warning guidance from the HulPA program for a case from Hurricane Earl. Again based on forecaster feedback, a table of the endpoints of the watches and warnings was added to the HuLPA output.

The automated watch/warning capabilities will be available for evaluation by the NHC forecasters during the 2011 season.

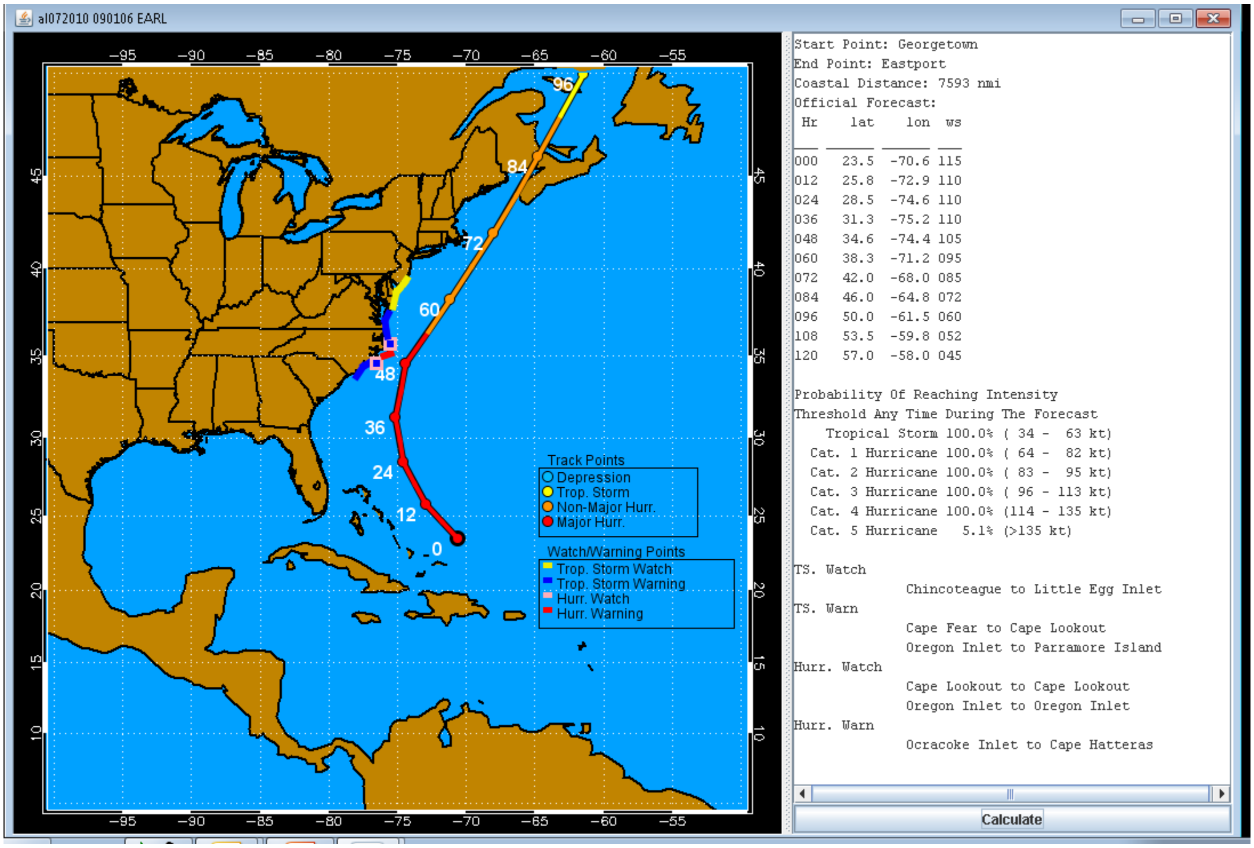

Figure 2. Screen capture showing an example of the automated watch/warning guidance for Hurricane Earl from the MC model run initialized at 01 Sept 2010 at 0600 UTC. The MC model from this run and the previous 48 h are utilized by the HuLPA program.

<u>Additional Applications</u>

Based on feedback from the 2010 season, the NHC forecasters suggested that additional capabilities be included in HuLPA, which were not in the original work plan. These include products that show the probability and cumulative probability distributions of the start and end times of the 34, 50 and 64 kt winds, and a method to show the tracks and intensities of all of the realizations. These new capabilities were added to HuLPA and will be available for forecaster evaluation in 2011. Examples are shown in Figs. 3 and 4.

<u>Code refinement 1. Time step adjustment.</u>

The MC model code was modified to allow the time step to be reduced from 2 to 1 hr. This change was implemented in 2010 and reduced the noise in the graphical products for small and fast moving storms. The 1 hr time step was also needed for several of the HuLPA products.

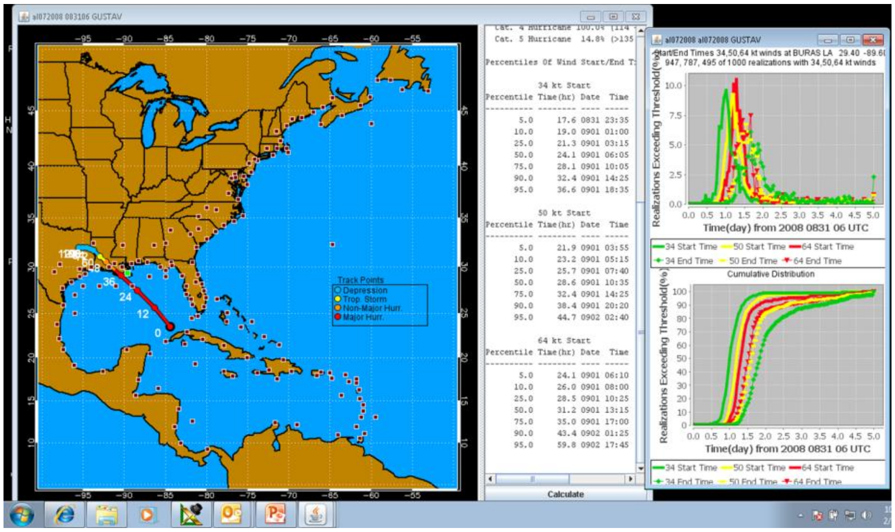

Figure 3. Screen capture showing the HuLPA product for displaying the distributions of the starting and ending times of 34, 50 and 64 kt winds at a user specified point for a case from Hurricane Gustav (2008). The selected point is indicated in green on the left panel.

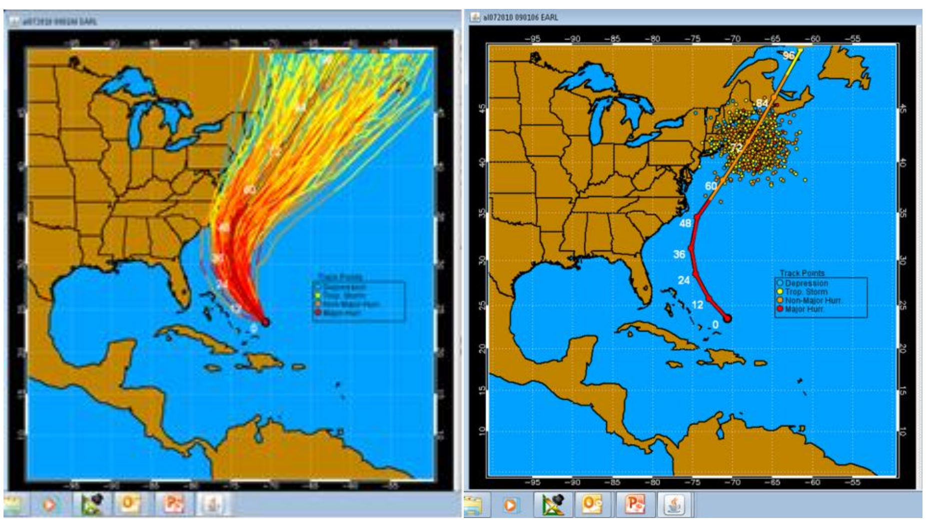

Figure 4. Screen capture showing the HuLPA product to display the tracks and intensities of all 1000 realizations for all forecast times (left) or at a single forecast time (right) for a case from Hurricane Earl (2010).

<u>Code refinement 2. Azimuthal interpolation of wind radii</u>

The wind radii in the MC model are determined from a simple climatology and persistence model, where the surface wind field is represented by a modified Rankine vortex. If used in its continuous form, the radii of each wind threshold (34, 50 and 64 kt) would be consistent. However, because the model includes a persistence component based on the 4 quadrant values from the NHC official forecast, the wind radii are azimuthally interpolated from the underlying vortex model evaluated in 4 quadrants. This interpolation works very well in most cases. However, in a few cases where the radii are zero in some quadrants for some wind thresholds but not for others, the interpolation can introduce inconsistency between the radii values. For example, the 34 kt radii can be smaller than the 50 kt radii for a small range of azimuth. The azimuthal interpolation was modified so that the radii can never be smaller than radius of maximum wind, which resolved this problem. The modified code will be implemented in 2011.

Code refinement 3. Spatial interpolation of probabilities

The MC model is run on a large domain with a 0.5^o lat/lon grid spacing and on a set of coastal points for text products. The large domain product is interpolated to a much finer grid for use in AWIPS and the National Digital Forecast Database (NDFD). In regions of large probability gradients, the interpolated gridded values do not agree perfectly with the corresponding values calculated directly at the specified coastal points. To evaluate the magnitude of these errors, a series of convergence tests were performed where the model was run with the spacing of the lat/lon grid equal to 0.5, 0.4, 0.3, 0.25, 0.2 and 0.1^o. The 0 to 120 h cumulative probabilities of the 34, 50 and 64 kt winds were linearly interpolated to coastal points utilized in the text product, and these were compared to the values where the probabilities were calculated directly at the coastal points. For the evaluation, large (Hurricane Ike) and small (Hurricane Charley) cyclone cases were considered. The Ike case was initialized on 01 September 2008 at 1200 UTC (about 48 h before its Texas landfall) and the Charley case was initialized on 13 August 2004 at 0000 UTC (about 24 h before its southwest Florida landfall).

Figure 5 shows the mean absolute error (MAE) of the 120 h cumulative 34 and 64 kt probabilities at the coastal points due to linear interpolation. Only those points within a few hundred km of the landfall location were included to exclude the large number of points where the probabilities were zero, which would artificially deflate the MAE. As expected, the errors are larger for the Charley case because the probability gradients are larger, due to the small size of the storm. Figure 5 indicates that the MAE due to interpolation could be cut in half simply by reducing the grid spacing on the computational grid to 0.25^o. Preliminary timing tests indicate that this would not cause a significant delay in the generation of the real time products.

The results in Fig. 5 show that even with the 0.5^o grid spacing, the average interpolation errors are between 1.5 and 4%, which are close to the underlying noise level of the MC model with 1000 realizations. However, the errors at a few points near the gradient regions can be much larger. Figure 6 shows the maximum and minimum errors for the Ike and Charley cases. This figure shows that magnitude of the interpolation errors can be as high as 25% with the 0.5^o grid spacing. Again, this can be reduced by a factor of two by halving the grid spacing. It is recommended that the spacing of the computational grid be reduced to improve the consistency with the text product.

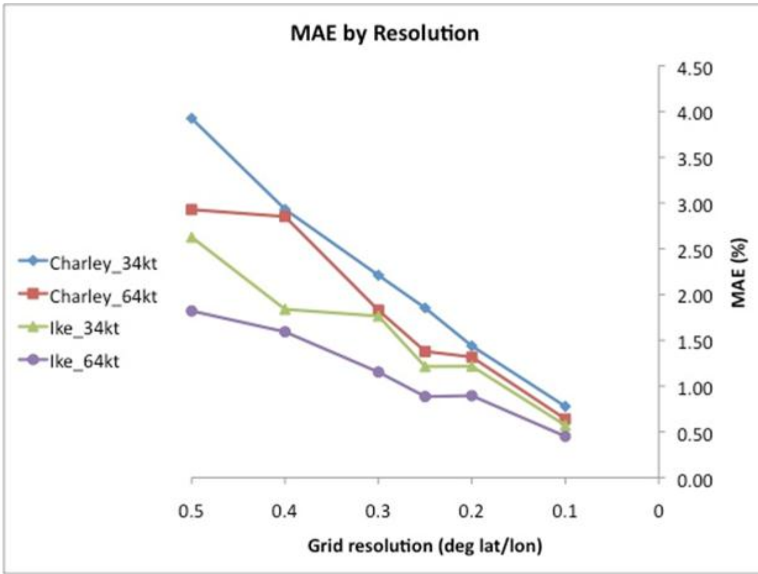

Figure 5. The mean absolute error of the 120 h cumulative probability of 34 and 64 kt winds due to linear interpolation from the evenly spaced lat/lon grid to the coastal locations for cases from Hurricanes Ike (2008) and Charley (2004).

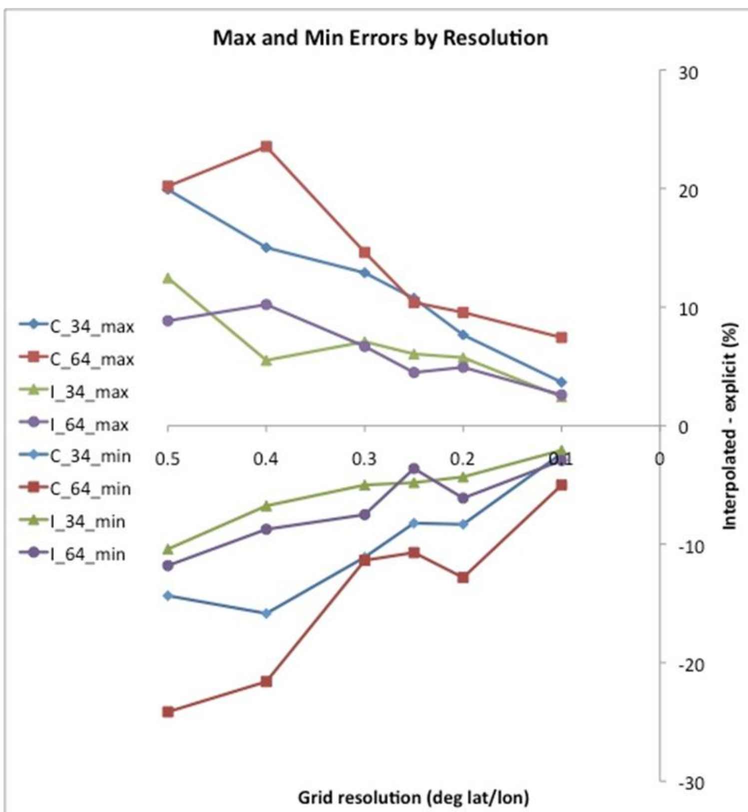

Figure 6. Same as figure 5, but for the maximum and minimum errors at any coastal point.

Code refinement 4. Radii model evaluation

Because NHC and JTWC do not forecast wind radii out to 120 h, the radii in the MC model are determined from a simple climatology and persistence wind radii model and its error distributions. An evaluation of the MC model wind radii was performed in Year 1. Results showed that the model does a reasonable job of reproducing the distributions of wind radii from the NHC best track. Given that the entire wind surface wind field must be estimated from just the track and maximum wind of each realization, there are few alternatives for the simple wind radii model, other than to apply a bias correction if the distributions were systematically different than the observations (which they are not). If NHC, CPHC and JTWC eventually provide wind radii forecasts for the entire forecast period, it may be possible to improve the wind radii estimation method.

3. Plans for the Second Half of Year 2

In remainder of Year 2, the new version of HuLPA that includes all of the applications, including the automated watch/warning guidance, will be provided to NHC for testing and evaluation during the 2011 season. We will also coordinate with NHC on reducing the grid spacing of the MC model to improve the consistency of the grid and text products. The MC model can already be run with the reduced grid spacing, but there are considerable downstream impacts on operational products that must be considered before that change can be made. That part of the processing is handled by NHC and needs to be coordinated with other parts of the National Weather Service.

To document the MC model and the new applications, a two part manuscript is in preparation for submission to Weather and Forecasting (DeMaria, et al, 2011b). This paper will be submitted before the start of the 2011 season.

References

DeMaria, M., R. DeMaria, A. Schumacher, D. Brown, M. Brennan, R. Knabb, P. Santos, D. Sharp, and S. Kidder, 2011a: Advanced applications of the Monte Carlo Wind Probability Model: A Year 2 Joint Hurricane Testbed Update. Presented at the 65th Interdepartmental Hurricane Conference, Feb. 28 – Mar 3, 2010 Miami, FL. <Available from http://www.ofcm.gov/ihc11/linking_file_ihc11.htm>

DeMaria, M., J.A. Knaff, M.J. Brennan, D. Brown, C. Lauer, R.T. DeMaria, A. Schumacher, R.D. Knabb, D.P. Roberts, C.R. Sampson, P. Santos, D. Sharp and K.A. Winters, 2011b: Operational tropical cyclone wind speed probabilities: Part I. Recent model improvements and Verification. To be submitted to *Wea. Forecasting*, April 2011.

DeMaria, M., J.A. Knaff, M.J. Brennan, D. Brown, C. Lauer, R.T. DeMaria, A. Schumacher, R.D. Knabb, D.P. Roberts, C.R. Sampson, P. Santos, D. Sharp and K.A. Winters, 2011b: Operational tropical cyclone wind speed probabilities: Part II. Advanced Applications. To be submitted to Wea. Forecasting, April 2011.

Appendix – Project Timeline

Year 1

Aug 2009	Project Begins
Oct 2009	Completion of the incremental probability verification (application II) for the Miami WFO
Nov 2009	Completion of the time step adjustment (code modification I)
Jan 2010	Completion of the wind radii consistency (code modification II)
Mar 2010	Addition of the landfall timing and intensity distribution calculation to the main MC model code (application I)
Mar 2010	Progress report at the IHC
May 2010	Modification of the MC model code on the IBM and ATCF for include code upgrades I and II, and the output for application I (landfall probabilities)
Jun 2010	Completion of the wind radii evaluation study (code modification IV)
Jul 2010	Completion of the first version of application the watch/warning guidance (application IV)

Year 2

Nov 2010	Development of line-integral probability capability (application III)
Dec 2010	Refinement of the wind radii model, if necessary (code modification IV)
Feb 2011	Completion of the text-gridded product consistency method (code modification III)
Mar 2011	Progress report at the IHC
May 2011	Implementation of line integral user interface for forecaster feedback (application III)
May 2011	Refined version of watch/warning guidance script for forecaster evaluation (application IV)
July 2011	Delivery of final versions of code and new applications depending on outcomes from NHC evaluation
July 2011	Project ends